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REPORT ON SOYA BEAN

BY

The Soya Bean Sub-Committee

of the Nutrition Advisory Committee,

Indian Research Fund Association

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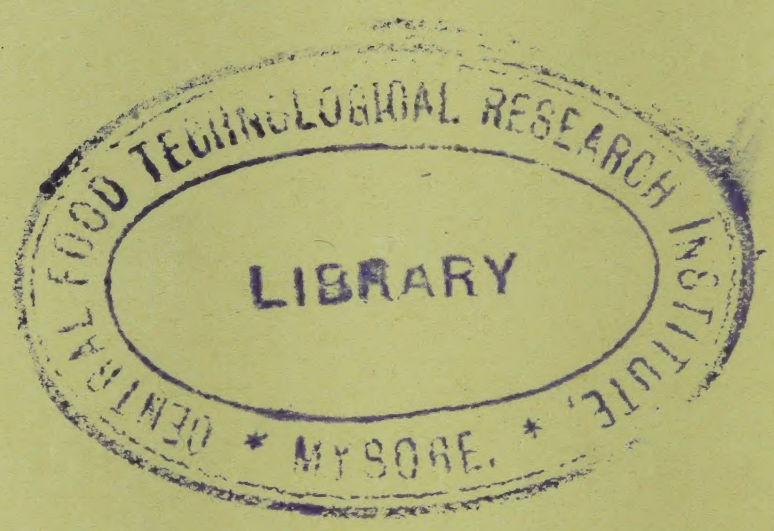

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REPORT ON SOYA BEAN

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The Soya Bean Sub-Committee of the Nutrition Advisory Committee, Indian Research Fund Association.

CHAPTER I.

INTRODUCTION.

(1) The soya bean (*Glycine hispida ; Glycine max ; Soja max ;*) is a native of the Far East. It has been cultivated in China, Manchuria and Japan from very early times, and is to-day an important article of diet in these countries. It was introduced into the United States as early as 1829 and into Europe in 1873. In 1790 it was grown in Kew gardens in England. Within the last 20-30 years it has become an important crop in the United States and improved varieties capable of thriving in that country have been developed. It has also been extensively grown in Eastern Europe. Table 1 shows acreage, yield and production in the United States during the years 1924 to 1941 (Dies, 1943).

TABLE 1.

Soya bean acreage and production.

(United States of America)

Crop year (October 1 to September 30)	Area (in thousands of acres)	Yield per acre (lbs.)	Production (in thousands of tons)
1924	448	605	122
1925	415	645	120
1926	466	615	129
1927	568	670	171
1928	579	750	194
1929	708	730	231
1930	1,008	735	331
1931	1,104	835	412
1932	977	840	368
1933	997	725	323
1934	1,539	825	568
1935	2,697	910	1,092
1936	2,132	775	738
1937	2,549	980	1,114
1938	3,105	1,110	1,543
1939	4,417	1,140	2,245
1940	4,779	885	1,903
1941	5,855	1,040	2,625

Table 1 shows that average yields rose from 600 to over 1,000 lbs. per acre during the period in question, while the total area under this crop increased 13 times and total production 21 times. In 1939 world production of soya bean was estimated as 7 million tons* (Dies, *loc. cit.*). Of this

*A report of the Empire Marketing Board (E.M.B./C./4., 1932) estimated world production at 15 million tons.

Manchuria produced 3·7 million tons and the United States 2·2 million tons. In Europe conditions of cultivation are less favourable ; for example yields in England have not exceeded 560 lbs., whereas in Japan, Manchuria and U.S.A., yields which are more than double this figure are often obtained. The crop takes from 85 to 170 days to ripen, depending on the variety and climate.

(2) Soya bean has been cultivated to some extent in India, but exact data about the extent of cultivation are not available. The following extract from a report written in 1941 by Dr. Burns, Agricultural Commissioner with the Government of India, may be quoted :—

> " E. J. Woodhouse and C. Somers Taylor in 1913 wrote a paper entitled, ' The Varieties of Soy Beans found in Bengal, Bihar and Orissa and their Commercial Possibilities '. In this they came to the conclusion that the Darjeeling varieties were probably originally obtained from China, through Tibet and had thence spread into the plains where only the types best adapted to plains conditions had survived. The cultivation of soy bean was then carried on only to a slight extent in the Darjeeling hills and to no appreciable extent anywhere else, though satisfactory yields had been obtained by the Agricultural Department in both hills and plains areas.
>
> In addition to the Darjeeling district of North Bengal, soy bean is grown also in Nepal, Bhutan and Sikkim, the total area in all these places being probably about 20,000 acres. Madras experience is summarised in an article ' Soy Bean Trials in Madras ' by M. Anandan in the Madras Agricultural Journal, September, 1940. In Madras an annual rainfall of 40 inches and deep alluvial soil seem to be necessary. Yields were from 350 to 2,000 lbs. per acre ".

(3) Considerable discussion has taken place in India on the subject of soya bean and its potentialities as a food crop. The bean contains some 40 per cent of protein and nearly 20 per cent of fat, and is a fair source of some of the B vitamins, calcium, phosphorus and iron. Its most striking property is its richness in protein and fat and it is this that has led to its advocacy by certain scientific workers as a highly nutritious article of diet. The movement so initiated has spread to members of the public and it has often been urged by soya bean enthusiasts that the widespread cultivation and popularisation of soya bean would do much to solve the problem of nutrition in India.

(4) Arguments in support of extending the production of soya bean include the following :—

(*i*) The soya bean, because of its high content of protein, fat, etc., would be an excellent supplement to poor cereal diets.

(*ii*) It is a high-yielding pulse giving a large return per unit area. It is capable of playing an important part in the rotation of crops.

(*iii*) It is a useful fodder crop. Soya bean cake from which the oil has been expelled is excellent feed for cattle.

(*iv*) The bean is of great industrial importance as a source of oil, raw materials for plastics, adhesives, etc.

This report is concerned mainly with (*i*), i.e. with the value of soya bean as an alternative food to pulses already in common use in India, and the questions referred to under (*ii*), (*iii*) and (*iv*) lie outside its scope.

(5) The Nutrition Advisory Committee, in the report of its third meeting held in 1937, commented on soya bean as follows :—

> " *Soya bean.* The nutritive value of soya bean has been studied by experiments on animals and also by controlled experiments on school children. The general conclusion is that soya bean, considered as a supplement to typical

> Indian diets, is not of outstanding value ; it does not appear to have any advantage over various common pulses which have long formed part of the diet of the Indian people. While it would be advisable that the results obtained in the Coonoor Laboratories should be confirmed elsewhere, existing data suggest that at present the encouragement of the production and consumption of soya bean need not be made a prominent part of nutritional and agricultural policy in India.

Some members of the Nutrition Advisory Committee were, however, dissatisfied with this expression of policy and the matter came up for discussion at subsequent meetings. The Committee, in general, felt that the question was one that required further attention and investigation. The report of its seventh meeting (December 1941) contains the following passage :—

> " While the validity of this (1937) recommendation was questioned by certain members of the Committee, it was agreed that there was insufficient unanimity among the members of the Committee to justify a further pronouncement on soya bean. It was decided that further work was necessary to elucidate the problem. Accordingly a sub-committee was appointed to suggest lines on which further experiments on soya bean might be carried out by different laboratories ".

The Sub-Committee*, at its first meeting in December 1941, expressed the view that " a co-ordinated investigation, to be carried out in a number of different laboratories, would help to solve differences of opinion ". It drew up a programme of work to be followed in the participating laboratories simultaneously, and laid down standard experimental techniques. The following four laboratories took part in the enquiry :—

(*i*) The Biochemical Laboratory, University of Dacca, under Dr. K. P. Basu.

(*ii*) The Seth G. S. Medical College, Bombay, under Dr. V. N. Patwardhan.

(*iii*) The University Chemical Laboratories, Lahore, under Dr. Bashir Ahmad.

(*iv*) The Nutrition Research Laboratories, Coonoor, under Dr. W. R. Aykroyd.

(6) The main problem for study was the nutritive value of soya bean in comparison with that of various pulses now commonly consumed in India. The work carried out under the auspices of the Sub-Committee fell under the following heads :—

(*a*) Study of the biological value of the proteins of soya bean and other pulses by metabolism experiments on adult rats at a 10 per cent level of intake.

(*b*) The same problem employing the growth method of assessing biological values, using young rats, the level of protein intake being 10 per cent.

(*c*) The effect of supplements of soya bean and other pulses on the growth of rats fed on a poor rice diet, and the same diet " fortified " by calcium and vitamins.

(*d*) The investigation of the biological value of soya bean and other pulses by metabolism experiments on human beings.

---

*The following are members :—

Dr. W. R. Aykroyd, Dr. K. P. Basu, Prof. B. C. Guha, Dr. V. N. Patwardhan and Dr. K. C. K. E. Raja.

(*e*) Study of the effect of soya bean and other supplements on the growth of school children.

(*f*) The vitamin content of soya bean and other pulses.

(7) The present report gives an account of the work carried out and the conclusions reached. In the opening chapters a review of the relevant literature on soya bean is given. It was felt that such a review would be of value to scientific workers and others in India interested in the subject.

(8) The workers concerned in the investigation, in addition to the heads of laboratories, included the following :—

(*i*) *The Biochemical Laboratory, University of Dacca :*
Dr. H. N. De, M.Sc., Ph.D.
Mr. P. K. Dutt, M.Sc.

(*ii*) *The Seth G. S. Medical College, Bombay :*
Mr. N. G. Nhavi, M.Sc.
Dr. (Miss) K. S. Radha, M.Sc., Ph.D.

(*iii*) *The University Chemical Laboratories, Lahore :*
Mr. Ahmed Ali Qureshi, M.Sc.
,, Tilak Raj Dutt, M.Sc.
,, Ved Rattan, M.Sc.

(*iv*) *The Nutrition Research Laboratories, Coonoor :*
Mr. A. R. Sundararajan, M.Sc.
,, N. K. De, M.Sc.

CHAPTER II.

THE COMPOSITION OF SOYA BEAN.

A. *Proximate principles.* (1) The proximate principles in soya bean as reported by various authors are shown below :—

Authority.	No. of samples.	Water	Protein (N×6·25).	Fat.	N-free extract.	Fibre.	Ash.
		(per cent.)					
Jenkins and Winton (1892)	8	10·80	33·98	16·85	28·89	4·79	4·69
Street and Bailey (1915)	19	10·00	38·29	14·89	26·64	4·64	5·54
Food (Editorial, 1935) ..	..	7·65	40·65	20·38	23·61	1·63	6·08
Law* (1936) ..	..	7·30	46·70	20·68	18·02	2·67	4·63
Ranganathan, Sundararajan and Swaminathan (1937) ..	..	8·08	43·22	19·50	20·85	3·72	4·63
Basu, Bose, Quader and De (1939) ..	..	11·50	41·20	17·50	21·50	4·20	4·10

*Figures relate to steam processed soya flour.

B. *Protein.* (2) There is considerable variation in the protein content of soya bean, as recorded in the literature. Piper and Morse (1916) examined over 500 samples grown at Arlington in the U.S.A. and reported values ranging from 31 to 46·9 per cent. The crude protein content (N × 6·25) of various samples of soya bean grown in India and used in

the present investigation, is shown below, together with typical values for 3 other pulses. The protein content of the soya bean samples, with one exception, was in the neighbourhood of 40 per cent.

	Protein (N×6·25) (per cent).
Soya bean, Manchurian variety grown in India ..	40·0
,, Kashmir	38·0
,, Punjab I	42·4
,, Punjab II	40·4
,, Bengal (green variety)	41·0
,, Lyallpur	32·8
Bengal gram (*Cicer arietinum*)	23·4
Red gram (Dhal arhar, *Cajanus indicus*)	22·6
Green gram (*Phaseolus radiatus*)	22·6

(3) The principal protein of soya bean is a globulin, glycinin (Osborne and Campbell, 1898). Most of this can be dissolved out in water from freshly ground seed. The total globulin, according to Muramatsu (1920), consists of glycinin (78·5 per cent) and phaseolin (21·5 per cent). He suggests the factor 5·82 for conversion of nitrogen in soya bean into protein.

(4) The nitrogen distribution in glycinin has been investigated by different workers. The results shown in Table 2, considering the different methods and varieties used by the workers in question, are reasonably concordant.

TABLE 2.

Nitrogen distribution in glycinin.

	Nollau (1915)	Jones & Waterman (1921)	Hamilton, Uyei, Baker and Grindley (1923)	Mashino and Nishimura (1927)
	(per cent)			
Humin N	3·69	0·97	2·87	6·14
Arginine N	15·52	15·35	15·70	15·55
Cystine N	1·52	0·80	1·46	1·74
Histidine N	2·60	2·38	5·60	7·03
Lysine N	7·02	10·27	6·18	6·08
Total basic or diamino N*	26·66	28·80	28·94	30·40
Mono-amino N ..	48·76	55·18	48·28	49·76
Non-amino N	7·12	2·93	10·95	5·19
Amide N	12·97	12·19	9·38	9·58
Total ..	99·20	100·07	100·42	101·07

*This is made up of arginine, cystine and lysine.

(5) The amino acid content of glycinin as reported by various workers is as follows (Table 3) :—

TABLE 3.

Amino acid content of glycinin.

	Osborne and Clapp (1907).	Jones and Waterman (1921).	Csonka and Jones (1933).	Barnes and Maack (1943).
		(per cent)		
Glycocoll ..	0·97	..	..	0·75
Alanine ..	..	..	..	1·7
Valine ..	0·68	..	..	..
Leucine ..	8·45	..	..	9·2
Isoleucine ..	..	..	..	2·4
Aspartic acid ..	3·86	..	..	5·7
Glutamic acid ..	19·46	..	..	19·0
Dopa ..	..	..	..	2·9
Tyrosine ..	1·86	..	3·94 to 4·55	3·9
Phenylalanine ..	3·83	..	..	4·3
Proline ..	3·78	..	..	4·3
Threonine ..	..	..	..	2·1
Tryptophane ..	..	1·37	1·89 to 2·84	1·7
Arginine ..	5·12	8·07	..	8·3
Lysine ..	2·71	9·06	..	5·4
Histidine ..	1·39	1·44	..	2·2
Valine ..	..	..	..	1·6
Cystine ..	..	1·18	0·74 to 1·46	1·1
Methionine ..	..	..	..	1·8
Ammonia ..	2·56	2·28	..	..

(6) Defatted meal prepared from different varieties of soya bean was found to contain the following : nitrogen 8·66 to 10·51 per cent ; cystine 0·287 to 0·491 per cent ; tryptophane 0·91 to 1·17 per cent and tyrosine 2·29 to 3·01 per cent (Csonka and Jones, 1936). These authors reported that the cystine content seemed to vary directly with N content, and that in feeding experiments a diet of soya bean of low cystine content may lead to cystine deficiency. Monnier (1935) suggested, on the basis of chemical analysis, that soya bean protein is compounded of casein and a vegetable nucleoprotein. Compared with wheat protein, soya flour protein contains significant amounts of lysine (Hafner, 1942).

(7) Mitchell and Smuts (1932) fed soya bean protein at a 10 per cent level to rats, using the paired feeding method, and concluded that soya bean protein was deficient in cystine. Shrewsbury and Bratzler (1933) confirmed these findings. On the other hand, Almquist, Mecchi, Kratzer and Grau (1942) who carried out growth experiments with chicks, at a 20 per cent level of protein intake, found that the methionine content of raw soya bean protein was 1·9 per cent, and concluded that this was its most important deficiency. Choline could not replace the methionine in the diet used in their experiments. From further experiments, Almquist and Grau (1944) concluded that a ration containing 13 per cent soya bean meal and 7 per cent sesame meal proteins would provide the methionine required for the optimum growth of the chicken.

(8) Iwamura (1936) reported that the addition of 0·1 to 1·0 per cent of cystine to a diet of polished rice and soya bean protein was necessary to produce normal growth in rats. Smuts and Marais (1939), in paired feeding experiments on rats, also found that the addition of cystine to a diet based on soya bean led to a definite increase in growth. At an intake of approximately 8 per cent of protein the biological value for the rat of raw soya bean was 55 ; by the substitution of 0·20 per cent cystine nitrogen for an equivalent amount of soya bean nitrogen the biological value increased to 74. Hayward, Steenbock and Bohstedt (1936b) consider that cystine or its equivalent probably exists in the protein of the raw soya bean in a form not available to the animal and that heating the bean makes the cystine fraction available, with the result that biological value is substantially increased. Equal growth responses were obtained when 0·3 per cent l-cystine was used to supplement the raw soya bean diet as when heated soya bean was given, or casein added at a 10 per cent level of intake. Hayward and Hafner (1941) noted that the autoclaving of soya bean, or the addition of 0·3 per cent of either cystine or methionine to raw soya bean, greatly increased the efficiency of the protein in promoting growth in rats and chicks. Methionine was more effective than cystine. Either in combination or individually the two amino acids further increased the efficiency of the autoclaved soya bean protein.

Gounelle, Bachet and Marche (1942) treated successfully seven patients suffering from hunger oedema, by the addition of 150 to 300 grammes daily of soya bean flour to their basal diet of 1700 calories containing 60 grammes of protein and 24 grammes of fat, whereas no benefit followed the administration of vitamins A, B complex, C, D or E. The soya bean, in addition to supplying a large amount of protein to the diet, supplied a fair amount of fat. They attributed the high fat content of soya bean to have had a sparing action on the protein of the diet, the deficiency of which they considered was the primary cause of famine oedema.

(9) *Biological value.* The biological value of soya bean proteins has been investigated by a number of workers using different species of animals, and at different levels of protein intake. Experiments on the effect of heating on biological value have also been reported in the literature. Mitchell and Villegas (1923) as a result of metabolism experiments on rats at a 10% level of protein intake reported the biological value of steam cooked soya bean flour to be 64. Smuts and Marais (*loc. cit.*) found the biological value of the proteins of raw soya bean to be 55 at an 8 per cent protein level. By growth experiments on rats at 11 per cent level of protein intake, Kon and Markuze (1931) found the biological value of soya bean flour processed by the Berczeller method to be 1·57. Boas Fixsen (1935) reviewed the literature on the biological value of the proteins of foodstuffs. She concluded that legume proteins are of poor biological value, largely owing to deficiency of cystine, and that they are poorly digested in the raw state.

(10) As the result of experiments on the growth of rats, Wan (1931) concluded that the proteins of soya bean are inferior to those of milk. Soya bean was, however, found to be a better source of protein than either wheat or maize. The addition of meat to a diet containing soya bean appeared to increase the assimilability of the soya bean protein (Eppelbaum, 1934). Practical studies involving the determination of supplementation values of soya bean proteins incorporated into other proteins, notably wheat flour, have been made by Harris, Clark and

Lockhart (1944) and by Jones and Divine (1944). According to Iwanowa (1935) the proteins of soya bean are of such a high biological value that no other protein supplement is required for the growing rat. Ferrin (1936) compared steam-rendered tankage* (60 per cent protein) with expeller processed soya bean oil meal in respect of their effect on the growth of pigs ; there was no significant difference in the rate of growth or in food consumption per unit gain in weight between the two groups. Harris, Work and Henke (1943), in experiments carried out on four steers on the utilisation of " soya bean oil meal " nitrogen at a 12 per cent protein level, found the true digestibility coefficient of the nitrogen to be 94.

(11) *The effect of heating on biological value.* Osborne and Mendel (1917), in experiments on rats with raw soya bean meal as the sole source of protein in the diet, found that there was comparatively little growth. Heating the soya bean in an electric oven at 110°C. for four hours failed to bring about any great improvement in growth, but when the meal was mixed with sufficient distilled water to make a thick mush, heated on the steam bath for three hours and subsequently dried in a current of air at 80°C. to 90°C., normal growth was obtained. Similar results followed when commercial " soy cake meal " was used as the sole source of protein, the good response in this case being attributed to the heat employed to facilitate the extraction of oil from the seed. Vestal and Shrewsbury (1935), in experiments on pigs, found roasted and cooked soya bean to have a higher nutritive value than raw soya bean, and that the former was superior to both tankage and " soya bean oil meal " for production. In further experiments on pigs and rats they noted that cooking or roasting the soya beans made them an excellent protein supplement to maize (Shrewsbury and Vestal, 1937). Wilgus, Norris and Heuser (1936), using chicks, found that in soya bean oil meals produced by the " expeller " and " hydraulic processes ", the protein efficiency of the meal varied with the temperature and time of exposure to heat. Hayward, Steenbock and Bohstedt (1936a), in growth experiments with rats, showed that the nutritive value of soya bean oil meals prepared by both " expeller " and " hydraulic processes " at medium or high temperatures was higher than that of meals prepared at low temperature, or of raw soya bean meal. When whole soya bean flour was autoclaved with steam at 17 lbs. pressure for one and a half hours, the protein was found to have a high nutritive value, and these findings were confirmed by nitrogen balance experiments with rats. They suggest that heating causes some essential protein fraction, which is unavailable in the raw soya bean, to become available for absorption and metabolic use. They concluded that a cystine fraction, or its equivalent, present in the raw soya bean protein is made available on heating and that the nutritive value for the growth of the rats may thereby be doubled (Hayward, Steenbock and Bohstedt, 1936b). In experiments on rats, Johnson, Parsons and Steenbock (1939) observed that although heat treatment did not improve protein digestibility it increased sulphur retention and thereby improved the nutritive value of the bean ; they suggested that there is in soya bean a complex containing sulphur and nitrogen, which is absorbed but cannot be used for tissue building unless first heated. Hayward and Hafner (1941) found that autoclaving soya bean, greatly increased the efficiency of the protein in promoting growth in rats and chicks. Mitchell, Hamilton and Beadles (1945) reported that the digestibility and biological value of the proteins

*Prepared from meat refuse.

of soya bean for rats could be increased by heat processing and concluded that the improvement in the nutritive value of the protein was due to an increase in the availability of the cystine fraction. When soya bean was autoclaved for 15 minutes at 17 lbs. pressure, the efficiency of the proteins for the growth of rats was improved by 400 per cent ; though germinated and immature raw beans were distinctly superior to mature beans, both these were inferior to the corresponding autoclaved preparations (Everson, Steenbock, Cederquist and Parsons, 1944). In experiments on chicks and pullets, baked soya bean meal gave better growth results than raw soya bean meal (Gericke and Van der Merwe, 1942). Heated soya bean protein at a 20 per cent level produced daily weight gains in chicks of 6·5 per cent, but a small supplement of methionine increased these to about 8 per cent, which is the increase to be expected from a typical diet of similar crude protein content (Almquist, Mecchi, Kratzer and Grau, 1942). Myburgh (1944) from experiments on rats in which three samples of soya bean oil meal were fed concluded that the heated meal was not only more palatable, but more digestible and had a higher protein efficiency.

On the other hand Basu, Nath and Mukherjee (1937) fed soya bean at 5, 10 and 15 per cent levels of protein intake to rats and reported that while the digestibility of the proteins was increased by steaming for three hours, the biological value decreased. Miller and Morrison (1944) carried out experiments on lambs with diets containing soya bean, and found that though the extraction of soya bean increased nitrogen digestibility and utilisation, heat treatment appeared to have little effect.

The great majority of workers are agreed that some form of heat treatment of soya bean improves the biological value of its proteins. In most of the reported experiments this improvement was produced by autoclaving. The effect of heat has been explained on the ground that a cystine fraction, previously unavailable, is liberated by this means.

(12) *The effect of extraction and germination.* In balance experiments on rats, Johnson, Parsons and Steenbock (1939) fed, at an 18 per cent level of protein intake, soya beans extracted with ether, hexane or hexane-methanol mixture, together with the extracted oil in each case ; no difference in biological value was observed in the proteins of the beans. Miller and Morrison (1944) obtained similar results with lambs ; they also found that the proteins of extracted soya bean meal, whether heat-processed or not, gave a higher digestibility and a greater nitrogen retention than those of raw soya beans or their flakes. Everson, Steenbock, Cederquist and Parsons (1944) tested 5 varieties of soya beans on rats at a 10 per cent level of protein intake and reported that germinated and immature raw beans were superior to mature beans. They also confirmed the beneficial effect of autoclaving, reported by numerous other workers.

C. *Fat.* (13) The fat content ranges from 14 to 22 per cent. Thomspon and Morgan (1912) give the following average constants for the oil :—

Specific gravity	... 0·9193	Neutralisation value	177·8
Saponification number	... 187·3	Ether number	... 188·4
Iodine number	... 129·7	Unsaturated fatty acids	84·7%
Reichert-Meissl number	... 5·3	Saturated fatty acids	8·61%
Hehner number	... 93·5	Glycerol	... 10·29%

(14) Durkee (1936) reported that the oil consisted chiefly of glycerides of unsaturated fatty acids including linoleic (51 per cent) and oleic (33 per cent), and that the iodine value was 134. Law (*loc. cit.*) reported 2·42 per cent lecithin is soya bean. Carter and Hopper (1942) grew ten varieties of soya bean under different soil and climatic conditions for five successive generations. They stated that, in general, the oil content was largely a varietal characteristic and that the iodine value was influenced equally by variety and climate, and expressed the view that varieties and strains of beans inherit their characteristic composition.

D. *N-free extract.* (15) The N-free extract of soya bean contains little starch—hence the popularity of soya bean preparations in the feeding of diabetics. According to an article in "Food" (1935), it contains sucrose 5·26 per cent, stachyose 5·66 per cent, araban 4·83 per cent, galactan 6·18 per cent, and phosphatides 3·08 per cent. Basu, Bose, Quader and De (1939) observed that of 21·5 per cent of total carbohydrate (excluding fibre) in soya bean, only 8·09 per cent was available, made up of glucose 0·115 per cent, fructose 0·179 per cent, sucrose 1·016 per cent and starch 6·775 per cent. Street and Bailey (*loc. cit.*) analysed the nitrogen-free extract and fibre which formed 31·08 per cent of the Hollybrook variety of soya bean and found it to be made up of the following :—

Galactan	4·86	Starch ..	0·50
Pentosans	4·94	Cellulose ..	3·29
Organic acid (calculated as citric)	1·44	Undetermined hemicelluloses ..	0·04
Invert sugar	0·07	Dextrin ..	3·14
Sucrose	3·31	Waxes, color, tannin etc. ..	8·60
Raffinose	1·13		

Levallois (1881) reported 11 per cent of galactan in soya bean. Pentosans, according to Berghesani (1910), exist in soya bean to the extent of 3·86 per cent. Miller and Robbins (1934) advocate cooked green, immature soya beans as a vegetable on the grounds that they contain unusually large amounts of protein, fat, calcium, phosphorus and iron as compared with most vegetables.

E. *Mineral content.* (16) Data regarding the mineral content of soya bean and some other pulses are shown in Table 4 (Basu *et al*, 1939). Soya bean is considerably richer in calcium than common cereals, with the exception of the millet ragi (*Eleusine coracana*). It is slightly superior in calcium content to the common pulses Bengal gram, green gram and red gram, and definitely richer in phosphorus than these pulses.

F. *Vitamin content.* (17) Soya bean, like other pulses, contains only small quantities of carotene (pro-vitamin A). It is a good source of thiamin and somewhat superior in this respect to other legumes. It is not rich in riboflavin and nicotinic acid. Burkholder (1943) assayed six varieties of soya beans for some of the B vitamins and reported the following average values in mg. per 100 grammes ; pyridoxine 0·64, biotin 0·061 and pantothenic acid 1·2. His values for thiamin, riboflavin and nicotinic acid are included in Table 5. On germination the riboflavin and nicotinic acid content of soya bean was found to increase (French, Berryman, Goorly, Harper, Harkness and Thacker, 1944). As far as existing knowledge goes, it appears that soya bean is, in general, somewhat superior in vitamin content to most other pulses, but that the difference in favour of the former is not striking. Reported vitamin values, including some obtained in the present enquiry, are shown in Table 5.

TABLE 4.

The mineral content of soya bean and other pulses as percentage of oxides on moist basis.

	Ash	CaO	P_2O_5	Fe_2O_3	K_2O	Na_2O	MgO	SO_3	Cl	SiO_2
Soya bean (*Glycine hispida*)	4·53	0·31	1·51	0·016	1·45	0·17	0·22	0·73	0·067	0·003
Bengal gram (*Cicer arietinum*)	3·59	0·15	0·82	0·007	0·84	0·10	0·13	0·49	0·023	0·017
Green gram (*Phaseolus mungo*)	2·81	0·15	0·94	0·009	0·96	0·10	0·14	0·43	0·031	0·020
Red gram (Arhar dhall) (*Cajanus indicus*) ...	3·28	0·13	1·13	0·009	1·09	0·15	0·19	0·54	0·039	0·030
Lentil (*Lens esculenta*)	2·20	0·08	0·76	0·006	0·76	0·08	0·09	0·35	0·034	0·024
Khesari (*Lathyrus sativa*)	2·81	0·09	0·93	0·010	0·94	0·13	0·15	0·45	0·026	0·014
Field pea (*Pisum sativum*)	3·12	0·09	1·05	0·006	1·12	0·12	0·17	0·47	0·033	0·047

Table 5.

The vitamin content of soya bean and other pulses.
(Values expressed in mg. per 100 grammes).

	Carotene			Thiamin			Riboflavin		Nicotinic acid	
	Previous Workers.	Present work.		Previous Workers.	Present work.		Previous Workers.	Present work.	Previous Workers.	Present Work.
		Bombay.	Coonoor.		Bombay.	Coonoor.		Bombay.		Bombay.
Soya bean	0·04 to 0·97 (1)	0·37	0·10	0·24 to 1·17 (1) 0·84 to 0·96 (6)	0·15	0·28	0·23 (6) 0·16 (1)	0·41	2·0 (6)	7·3
Bengal gram (*Cicer arietinum*)		0·53	0·30	0·49 (2) 0·45 (3)	0·27	0·44	...	0·22	2·0 (2) 2·7 (5)	7·5
Red gram (*Cajanus indicus*) ...	0·26 (1)	0·51	0·14	0·38 (2) 0·38 (3)	0·14	0·13	0·07 (1)	0·28	2·4 (2) 1·9 (4) 2·4 (5)	2·2
Green gram (*Phaseolus radiatus*) ...	0·16 to 0·66 (1)	0·12	0·17	0·45 (3)	0·13	0·19	0·08 (1)	0·11	1·7 (4)	1·0
Black gram (*Phaseolus mungo*) ...	... ...	...	0·12	0·41 (3)	...	0·26	0·07 (1)	...	1·6 (4) 2·3 (5)	...
Horse gram (*Dolichos biflorus*) ...	0·08 to 0·16 (1)	...	0·10	0·52 (2)	...	0·10	...	...	2·3 (2)	...
Cow gram (*Vigna catiang*)	0·54 (1)	...	...	0·83 (2)		0·11	0·31 (1)	...	1·8 (2)	...
Kesari dhall (*Lathyrus sativus*) ...	0·20 (1)	...	0·14	...	...	0·34	...	...	...	...
Massur dhall (*Lens esculenta*)	0·05 to 0·45 (1)	...	...	0·12 to 0·63 (1) 0·41 (3)	...	0·32	0·07 (1)	...	1·5 (4)	...

(1) Boas Fixsen, M.A., and Roscoe, M. H. (1940).
(2) Bhagvat, K. (1943).
(3) Swaminathan, M. (1942a).
(4) *Idem.* (1942b).
(5) Giri, K. V., and Naganna, B. (1941).
(6) Burkholder, P. R. (1943).

CHAPTER III.

SOYA BEAN IN THE FEEDING OF INFANTS AND CHILDREN.

(1) The use of soya bean in the feeding of infants and children is relevant to the questions under discussion in this report. Soya bean has usually been given to infants in the form of " soya bean milk ", prepared by diluting the white milky fluid extracted from fresh beans. With suitable dilution the composition of the fluid approximates in protein and fat content to cow's or human milk. The following is a description of a method of preparing soya bean milk advocated by Professor V. Subrahmanyan, Indian Institute of Science, Bangalore. In this method, the beans are germinated before extraction.

> " The bean is steeped in water for 5 hours and then germinated for two days. It is then taken out and the skin removed by rubbing. The yellow to pale yellow kernel which is thus obtained is washed once or twice and then heated for half an hour with some fresh quantity of water at a temperature (about 80°C.) which is a little short of boiling. This heating further softens the kernel and extracts out some of the colouring matter as also the bitter principle which is present largely at the surface. Addition of a little washing soda or glycerine improves the efficiency of extraction, but may not be necessary in household practice. The water is then poured out and the kernel again washed to remove the adhering matter. It is then ground to a fine paste. To the paste, about three times its volume of water are added and the suspension is then heated to vigorous boiling for 30 minutes. The milky fluid is then allowed to cool and settle down. Even this is usually sufficient for removing the coarse particles. The creamy milk which is on top can then be decanted out and used for a variety of purposes. The average composition of the milk thus obtained has been determined and found to be as follows :—
>
> | | |
> |---|---|
> | Total solids | 10·15 per cent. |
> | Protein | 4·2 ,, ,, |
> | Fat | 3·4 ,, ,, |
> | Carbohydrate | 1·8 ,, ,, |
> | Salts | 0·75 ,, ,, |
>
> The vitamin content per litre of soya milk, prepared as above, and that of cow's milk is given below :
>
> | | | Soya milk | Cow's milk |
> |---|---|---|---|
> | Vitamin A | ... | 750 I.U. | 1,050 I.U. |
> | Thiamine | ... | 0·82 mg. | 0·43 mg. |
> | Riboflavin | ... | 1·10 ,, | 1·32 ,, |
> | Nicotinic acid | ... | 2·49 ,, | 1·16 ,, |
> | Ascorbic acid | ... | 21·6 ,, | 17·8 ,, |

(2) The literature on the use of soya bean milk in infant feeding was comprehensively reviewed by Mackay (1940). Since some of the articles referred to by this worker are not available in India, it is convenient to quote a passage from her report in full :

> " The largest series of cases yet published are those of Rittinger with his associates Dembo (1932) and Torrey (1935) who have given soya milk to 205 infants. They gave at first a wet-ground flour, with added sugar, fats and minerals. The majority of babies gained well, and had three to four large green soft stools daily. Some with six or seven stools daily did not thrive. The stools improved if the mixture was well boiled. Nevertheless with a wet-ground flour which may turn rancid, causing destruction of vitamin A and vitamin E, there is presumably considerable risk of symptoms of vitamin A deficiency developing (Horvath, 1938). As already pointed out, the composition of wet-ground flour varies widely with the details of preparation. Later, Rittinger and his colleagues (1935), used a dry-ground flour with or without partial breast feeding, adding more carbohydrate than in their earlier work. The infant's weight curves paralleled the Holt line for the most part,

but the majority were below it. Adding skimmed milk and wheat germ to the diet improved growth. They carried out X-ray and biochemical investigations, and blood counts in some cases, with normal results in nearly all instances.

In China, Tso and his associates (1928, 1931) used a wet-ground flour, with additions of sodium chloride, sugar and other substances, and carried out various metabolic studies on infants. They concluded that calcium is inadequate in such ' Milk ' (Tso, Yee and Chen, 1928), and that in order to furnish sufficient proteins 18 per cent of the total calorie intake should be provided by the protein (Tso and Chu, 1931). Chang and Tso (1931) suggest the use of a wet-ground flour with added sugar, dried by a spray process to which is added before use more sugar and calcium lactate, sodium chloride, cod liver oil and cabbage water. Following this work, a wet-ground flour, prepared at the local health station, was used in Peiping by Guy and Yeh (1938a), because of the urgent need of an artificial food cheaper than cow's milk. They too made various additions to the flour (sugar, starch, calcium lactate, sodium chloride). They used ' soymilk ' as a supplement to breast feeding, giving, like Chang and Tso, cod liver oil and cabbage soup to supply vitamins D and C. They found that the babies had less muscular vigour than the breast fed ones and were subnormal in weight. They concluded that this method of preparation was cumbersome and impractical for their purpose. Later they fed forty-nine babies on a similar mixture but used a hand-ground flour made from roasted beans (1938b). They considered these results satisfactory inspite of a few failures. "

(3) Lanzing and Van Veen (1937) prepared soya bean milk approximating in composition and vitamin content to cow's milk by the addition of sugar, coconut oil, salt, calcium carbonate and boiled papayya juice. They advocated the use of such milk for feeding children but not infants.

(4) Mackay sums up the literature on infant feeding with soya bean as follows :

" No authors have published any detailed statistical results whereby the progress of babies given soya preparations can be compared with that of similar babies living under similar conditions but given preparations of cow's milk. Judging by the statements and conclusions of the authors quoted above, it seems, as might be expected, that babies fed on soya flours without any admixture of cow's milk do not, on the whole, make a good progress as babies having milk as the basis of their diet. "

(5) Mackay herself used a mixture of equal parts of soya bean flour and dried whole milk in the feeding of infants. The flour was prepared by a modification of the Berczeller process. The mixture was given to 48 infants under 5 months in age, while a similar group of 102 infants given milk alone served as control. Both groups received orange juice and cod liver oil, and after the age of 6 months other foods were supplied in addition to milk and the soya bean milk preparation, to which the name " Yolac " was given. According to the criteria increase in weight, haemoglobin levels, calcification of bones, morbidity and tolerance of the diet, the group receiving " Yolac " did as well as the controls, and Mackay advocated the use of " Yolac " as a cheap substitute for cow's milk.

(6) The general conclusion appears to be that soya bean preparations, if fed to infants, need to be supplemented by minerals and vitamins and that even after such supplementation they are less satisfactory than breast milk or cow's milk. The best and most convincing results are those reported by Mackay with " Yolac ". The milky extract of soya bean alone is not a satisfactory substitute for milk in infant feeding. It is clear the question of using soya bean in the feeding of infants and children in India needs to be approached on an experimental basis, and with caution. A necessary preliminary step would be careful trial in infant welfare centres of suitably supplemented preparations of soya bean. A mixture such as that successfully used by Mackay might be given a trial. Until

investigations along these lines have been carried out, there are insufficient grounds for advocating the general use of soya bean "milk" in infant feeding in this country.

Rat experiment with soya bean milk. (7) An experiment was carried out at Dacca on the comparative supplementary effect to a poor rice diet of cow's milk and soya bean milk. The soya bean milk was prepared as follows. Soya bean, previously soaked in water for 24 hours was lightly rubbed and washed to get rid of the seed coat and ground and into a fine paste in a stone mortar with the minimum amount of water. This was mixed thoroughly with three times its volume of water, filtered through a muslin and the filtrate boiled and used. The average composition of the soya bean milk, prepared as above, and, for the purpose of comparison, that of cow's milk is given below :

	Soya bean milk	Cow's milk
Specific gravity	1·031	1·026
Total solids	10·02	9·13
Protein	3·78	3·42
Fat	3·92	2·85
Mineral matter	0·43	0·67

Twelve young rats, 50 to 60 grammes in weight, equally distributed between the sexes were used in each group. One group was fed the poor rice diet (detailed in Chapter V) cooked *ad lib* while each rat in the other two groups received supplements of 10 ml. of cow's milk or 10 ml. of soya bean milk daily. Growth was observed over a period of eight weeks with the following result.

		Average increase in body weight per rat per week (g.)
Poor rice diet		3·44
do.	+cow's milk 10 ml. per rat daily	8·65
do.	+soya bean milk 10 ml. per rat daily	7·25

Experiment on school children. (8) Aykroyd and Krishnan (1937) carried out an experiment in a hostel in South India in which a group of children (girls) were given 1·5 ozs. of cooked whole soya bean, as a supplement to a poor rice diet, for a period of 20 weeks. Changes in weight in this group, and a similar control group without soya bean, were recorded. Both groups lost weight, but that receiving soya bean lost more than that receiving no supplement. The actual average figures were 2·37 and 0·62 lbs. decrease in weight respectively.

(9) A school-feeding experiment was carried out in Lahore as part of the present series. One hundred and twenty boys in day school, between the ages of 13 and 15, were placed at random into 4 groups. The boys belonged to families of low economic level, with family incomes below Rs. 100/- per month and it may be assumed that their diet, based on wheat, was relatively deficient in supplementary and protective foods. The boys in the four groups received the following supplements daily at school in addition to food taken at home.

Group I	1 oz. of soya bean.
Group II	1 oz. of dal mash (black gram).
Group III	12 oz. of liquid whole milk.
Group IV	No supplement.

(10) The experiment was continued for 8 months, height, weight and chest measurements being taken at the beginning and the end of the experimental period. The largest average increase in weight occurred in the group receiving milk ; the average initial weight of the boys in this group was, however, greater than that of the other groups. The small number of boys in the various groups rendered fully satisfactory interpretation of the results difficult. Statistical analysis, however, showed that the group receiving soya bean showed no significant advantage, as regards increase in weight, over the group receiving " dal-mash ". This is the point of importance, as far as the present report is concerned.

CHAPTER IV.

THE INVESTIGATION OF THE BIOLOGICAL VALUE OF THE PROTEINS OF SOYA BEAN AND OTHER PULSES.

The question was studied in the participating laboratories using uniform methods.

A. *Balance sheet experiments.* (1) The nitrogen-free basal diet had the following composition :—

	Parts
Starch	73·2
Sugar	9·0
Butter	10·0
Salt mixture (Osborne and Mendel)	5·0
Calcium Carbonate	0·8
Shark liver oil	2·0

An acid aqueous extract of yeast (3 ml., equivalent to 0·75 grammes of dried yeast) was given to each rat daily.

(2) The soya bean and pulses were included in this diet, in place of starch, in such proportions that the proteins were given at a 10 per cent level. Rats 130 to 160 g. in weight and aged 4 to 6 months were used as test animals. Six rats, including equal numbers of males and females, were used for each metabolism experiment. Before the test substances were fed, the nitrogen-free diet was given for 7 days ; to determine endogenous nitrogen excretion, the urine and faeces were collected for the last 4 days of this period. The mixed diets containing pulses were fed for 8 days, during the last four days of which urine and faeces were collected.

(3) The diets were steam-cooked for 15 minutes. Urine and faeces were collected daily. Urine was preserved with 5 cc. of 5 per cent sulphuric acid containing phenol and thymol and kept in the refrigerator in stoppered bottles. At the end of the experiment the total urine was made up to a standard volume and aliquots taken for nitrogen determination. Faeces were dried in an oven at 100°C., weighed, made into a uniform powder in a mortar and aliquot portions taken for analysis.

(4) The biological value and digestibility co-efficient were calculated using the following formulae :—

$$\text{Biological value} = 100 \times \left[1 - \frac{(\text{Total urine N} - \text{Endogenous N})}{\text{Food N} - (\text{Faecal N} - \text{Metabolic N})} \right]$$

$$\text{Digestibility co-efficient} = 100 \times \frac{\text{Food N} - (\text{Faecal N} - \text{Metabolic N})}{\text{Food N}}$$

The experiments were carried out in two series, one in 1942 and the other in 1943. The results are given in Table 6 and Table 6A respectively.

Table 6.

The biological value and digestibility coefficient of soya bean and other pulses by the balance sheet method on rats at a 10% level of protein intake (diet steam-cooked).

	Crude protein % (N×6·25)	Biological value — WORK CARRIED OUT AT				Digestibility coefficient — WORK CARRIED OUT AT				"Available" or "net" protein % — WORK CARRIED OUT AT				
		Bombay.	Coonoor.	Dacca.	Lahore.	Bombay.	Coonoor.	Dacca.	Lahore.	Bombay.	Coonoor.	Dacca.	Lahore.	Average.
Soya bean, Manchurian	40·0	57·5	65·0	47·5	74·0	91·4	96·0	80·5	...	21·1	25·0	15·3	...	20·8
Bengal gram	23·4	61·1	73·0	63·0	...	86·6	88·0	91·0	...	12·4	15·0	13·4	...	13·6
Red gram	22·6	64·8	63·0	52·0	...	86·2	77·8	89·0	...	12·6	11·1	10·4	...	11·4
Green gram	22·6	47·7	53·0	50·0	...	84·9	74·6	91·0	...	9·1	8·9	10·2	...	9·4

Table 6A.

The biological value and digestibility coefficient of soya bean and other pulses by the balance sheet method on rats at a 10% level of protein intake (diet steam-cooked).

	Crude protein % (N×6·25)	Biological value — WORK CARRIED OUT AT				Digestibility coefficient — WORK CARRIED OUT AT				"Available" or "net" protein % — WORK CARRIED OUT AT				
		Bombay.	Coonoor.	Dacca.	Lahore.	Bombay.	Coonoor.	Dacca.	Lahore.	Bombay.	Coonoor.	Dacca.	Lahore.	Average.
Soya bean, Kashmir	38·0	55·9	59·8	44·1	58·9	76·2	87·4	89·0	80·7	16·3	19·9	14·9	18·0	17·3
Soya bean, Punjab I	42·4	65·0	73·2	51·0	66·0	92·2	96·3	91·0	...	25·5	29·9	19·6	...	25·0
Soya bean, Punjab II	40·4	...	76·5	48·1	...	...	89·8	90·5	...	...	27·8	17·6	...	22·7
Soya bean, Bengal green	41·0	...	47·4	50·0	...	...	85·6	90·0	...	...	16·6	18·4	...	17·5
Soya bean, Lyallpur	32·8	63·4	69·3	...	67·0	84·0	84·9	...	79·6	17·5	19·3	...	17·5	18·1
Bengal gram	20·0	70·0	73·0	63·0	63·0	84·6	81·7	92·0	80·5	11·8	11·9	11·6	10·2	11·4
Red gram	23·6	55·0	...	53·0	74·0	76·9	...	90·0	67·1	10·0	...	11·2	11·7	11·0
Green gram	24·2	49·0	52·5	50·0	66·0	86·2	82·6	90·0	76·2	10·2	10·5	10·9	12·2	11·0

(5) It is to be observed from Tables 6 and 6A that there was considerable variation in the values obtained for the same sample in the various laboratories, and also in those obtained for different samples of soya bean in the same laboratory. No doubt a wide range of variation is to be expected in biological experiments of this nature, particularly when these are carried out by different workers in different laboratories, using different stocks of rats. In spite of the variation in results, the biological values recorded for Bengal gram were consistently higher than those recorded for soya bean, and those for green gram in general lower. The tentative conclusion is that soya bean is intermediate among common pulses as regards the biological value of its proteins and certainly has no special superiority in this respect. On the other hand, the " available " or " net " protein values were considerably higher for soya bean than for the other pulses, because of the higher crude protein content of the former.

B. *The growth method.* (6) For each test 12 rats, weighing from 40-50 g., with equal sex distribution, were used. The diets were the same as in the previous experiments, proteins being given at a 10 per cent level The rats were weighed weekly and the experiments were continued for a period of 9 weeks. Biological value was calculated according to the following formula :

$$\frac{\text{gain in body weight (grammes)}}{\text{protein intake (grammes)}}$$

(7) In a preliminary series of experiments carried out in Coonoor, the diets were given uncooked and it was observed that all the rats given the uncooked red gram diet died in 4 to 5 weeks. It appears that raw red gram contains a factor which is toxic to rats. The biological value of the other pulses, obtained with the uncooked diets, were as follows :

	Biological value.
Soya bean	0·4
Bengal gram	0·8
Green gram	0·7

In subsequent experiments the diets were given after being steam-cooked for 15 minutes, in Coonoor as in the other laboratories. The results obtained in experiments carried out in 1942 and 1943 are given in Tables 7 and 7A respectively.

TABLE 7.

The biological value of soya bean and other pulses on rats by the growth method at a 10% level of protein intake (diet steam-cooked).

	Biological value				
	Work carried out at				
	Bombay.	Coonoor.	Dacca.	Lahore.	Average.
Soya bean, Manchurian ...	0·51	0·74	0·78	0·89	0·86
Bengal gram ...	1·31	0·79	1·05	1·31	1·12
Red gram	0·82	0·72	0·82	0·70	0·77
Green gram	0·56	0·72	0·86	0·95	0·78

TABLE 7A.

The biological value of soya bean and other pulses on rats by the growth method at a 10% level of protein intake (diet steam-cooked).

	Biological value				
	Work carried out at				
	Bombay.	Coonoor.	Dacca.	Lahore.	Average.
Soya bean, Kashmir ...	1·22	0·79	0·97	0·78	0·94
Soya bean, Punjab I ...	1·24	0·90	...	...	1·07
Soya bean, Punjab II ...	...	0·75	0·88	...	0·82
Soya bean, Bengal green ...	...	0·70	0·86	...	0·78
Soya bean, Lyallpur ...	1·63	0·70	...	...	1·17
Bengal gram	1·68	0·77	1·07	1·33	1·21
Red gram	...	0·58	0·81	...	0·70
Green gram	...	0·71	0·76	...	0·74

(8) In this series of experiments there was again wide variation in the values reported from the different laboratories. In general, however, Bengal gram was again found to be somewhat superior to soya bean and other pulses. The conclusion to be drawn from these experiments is that the biological value of soya bean proteins, as determined by the growth method on rats, is approximately of the same order as that of the proteins of the other pulses.

C. *The effect of heat on biological value.* (*a*) *Balance sheet method.* (9) Samples of soya bean, Bengal gram and green gram, were autoclaved for 2 hours in steam at 125°C. Biological value and digestibility co-efficients were determined by the balance sheet method on adult rats at a 10 per cent level of protein intake. The procedure was exactly the same as in the balance experiments reported above. The results of these experiments, which were carried out in Dacca, are shown in Table 8. Values given by the steam-cooked pulses are included for purposes of comparison.

TABLE 8.

Effect of autoclaving on the biological value and digestibility coefficient of soya bean and other pulses by the balance sheet method on rats at a 10% level of protein intake.

	Treatment	Crude protein% (N×6·25)	Biological value	Digestibility co-efficient	'Available', or 'net' protein%
Soya bean, Kashmir ...	S.C.	38·0	44·1	89·0	14·9
do. do. ...	A.T.	38·0	63·6	91·5	22·1
Soya bean, Punjab I ...	S.C.	42·4	51·0	91·0	19·6
Soya bean, do. ...	A.T.	42·4	64·0	94·0	25·4
Soya bean, Punjab II ...	S.C.	40·4	48·1	90·5	17·6
Soya bean, do. ...	A.T.	40·4	63·8	94·0	24·3
Bengal gram ...	S.C.	20·0	63·0	92·0	11·6
do.	A.T.	20·0	59·3	92·0	11·0
Green gram	S.C.	24·2	50·0	90·0	10·9
do.	A.T.	24·2	38·6	83·0	7·8

Note:— S. C. = Whole diet steamed for 15 minutes.

A. T. = The pulse was autoclaved for 2 hours at 125°C. in steam and incorporated in the steam-cooked diet.

(10) It will be seen that autoclaving definitely raised the biological value of soya bean proteins as tested by this method. This is in conformity with the results of other workers. It may be noted that the biological values of the three samples of soya bean after autoclaving were closely similar. In the case of Bengal gram, and green gram, autoclaving appeared to reduce the biological value, an observation for which no immediate explanation can be given. Autoclaving had little effect on the digestibility of the proteins of the various pulses.

(*b*) *The growth method.* (11) These experiments were carried out in Lahore. The method of testing followed was as previously described. Samples of soya bean, Bengal gram and green gram were tested after being subjected to various treatments as detailed in Table 9. In the reported experiments the autoclaving of soya bean did lead to an appreciable increase in biological value, in comparison with the value given by steam-cooked beans, but the experiments are too limited in scope for conclusions to be drawn. In the case of Bengal gram and green gram, parching produced some *increase* in biological value.

TABLE 9.

Effect of heat treatment on the biological value of soya bean and other pulses by growth method on rats at 10% *level of protein intake.*

	Treatment.	Crude protein%.	Biological value.
Soya bean, Manchurian	S.C.	40·0	0·89
,, ,, ,,	B	,,	1·10
,, ,, ,,	A	,,	1·50
Bengal gram ..	S.C.	20·0	1·33
,, ,, ..	A	,,	1·70 ; 1·77
,, ,, ..	P	,,	1·83
Green gram ..	S.C.	24·2	0·71
,, ,, ..	P	,,	1·04

Note:—S.C. = Whole diet steamed for 15 minutes.

B. = The beans after being soaked in water were baked in an oven at 120°C for half an hour and incorporated in the steam-cooked diet.

A. = The beans were autoclaved for half an hour at 120°C in steam and incorporated in the steam-cooked diet.

P. = The beans were parched at a high temperature, and incorporated in the steam-cooked-diet.

D. *The biological value of the proteins of soya bean and other pulses as determined by metabolism experiments on human subjects.* (12) A number of experiments of this nature have been reported in the literature. Mendel and Fine (1911) reported that about 85 per cent of the nitrogen in cooked soya bean was utilised by adult male subjects. Experiments on 4 healthy young women were carried out by Rose and MacLeod (1925). The subjects were given a diet containing 4 grammes of nitrogen derived from soya bean ; nitrogenous equilibrium was maintained on this low intake and it was concluded that soya bean proteins were efficiently utilised by human beings. Cheng, Li and Lan (1941) carried out metabolism experiments with soya bean curd protein on 3 young adult male Chinese at a 2·6% level of intake, and reported a biological value of 64 and digestibility co-efficient of 97. The biological value and digestibility co-efficient of

soya bean, soya flour and soya bean milk were determined by Cahill, Schroeder and Smith (1944) on 10, 6 and 9 young adult male subjects respectively. The whole beans and the flour given in these experiments were autoclaved for one hour ; the soya bean milk was not autoclaved, but heat was employed in its preparation. The proteins were fed at a 5 per cent level of intake. The average digestibility was reported to be 90·5, 94·0 and 89·6 in the case of the 3 test materials respectively. Biological value was compared against that of whole egg proteins at a 5 per cent level of intake, since " whole egg proteins fed at a 5 per cent level of intake have given the highest biological value of any known human food when fed to adult rats (Mitchell and Carman, 1924 ; Sumner, 1938) ". Taking the biological value of egg proteins to be 100, the authors reported that of the 3 soya bean preparations to be 94·5, 91·7 and 95·3 respectively. In experiments on human subjects, Murlin, Edwards and Hawley (1944) found the average biological value of soya bean proteins to be 81 and that of whole egg proteins to be 97 ; the corresponding digestibility coefficients were 89 and 96 respectively.

(13) Metabolism experiments were carried out in Dacca on three healthy young men, S.C.T. (19 years), I.B.S. (19 years) and A.K.M. (18 years), weighing respectively 51, 49 and 47 Kg. The subjects were fed a diet almost free from nitrogen, with the composition shown below, for 6-9 days, after which the test diets containing the pulses were taken, the latter being incorporated after cooking in the diet in such quantities that daily intake of protein was approximately 80 g. Strict supervision was exercised over the experimental subjects, who carried out their ordinary duties in the laboratory, except during the period when the nitrogen-free diet was consumed. Urine and faeces were collected during the last 3 days of feeding with the test diets containing pulses. Urine, collected quantitatively for a 24 hours period, was preserved over toluene to which a few ml. of 5 per cent phenol were added and the total excretion was recorded. Faeces were preserved with a small quantity of glacial acetic acid dried on a water bath with frequent addition of alcohol, powdered, weighed and kept in the refrigerator in stoppered bottles. Total nitrogen was determined by the Kjeldahl method.

Nitrogen-free diet.

Sago	550 g.
Plantain	50 g.
Sugar	150 g.
Butter fat	50 g.

Test diets.

Butter fat	50 g.
Sugar	100 g.
Test pulse in quantities sufficient to supply 80 g. of protein.	

A typical test diet.

Butter fat	50 g.
Sugar	100 g.
Soya bean	194·6 g.
Sago	455·6 g.
Sago to make the total weight of the diet 800 g.	

The results of the experiment are shown in Table 10.

TABLE 10.

The biological value and digestibility co-efficient of soya bean and pulse proteins by human metabolism experiments (10 *per cent level of protein intake*).

	Crude Protein % (N × 6·25)	Biological value Subjects.				Digestibility co-efficient. Subjects.				'Net' protein %
		SCD	IBS	AKM	Aver.	SCD	IBG	AKM	Aver.	
Soya bean, Kashmir	38·0	43	..	42	42·5	94	..	88	91·0	14·7
,, Punjab I	42·4	..	..	59	59·0	..	..	92	92·0	23·0
,, Punjab II	40·4	58	58	57	57·3	95	91	91	92·3	21·5
Bengal gram ..	20·0	63	63	64	63·7	94	93	94	93·7	11·9
Red gram ..	23·6	62	63	60	61·7	92	90	90	90·7	13·2
Green gram ..	24·2	43	..	..	43·0	94	..	..	94·0	9·8

(14) As shown in Table 10, the biological value and digestibility co-efficients of soya bean and the other pulses for the experimental subjects were of the same order. The biological value for soya bean was considerably lower than those reported above by other workers who have carried out similar experiments on human subjects, but it should be observed that the level of protein intake was higher in the Dacca investigations. The high crude protein content of soya bean is reflected in the figures for "available" or "net" protein content, which, except in the case of one variety of soya bean, were nearly double those recorded in the case of the other pulses.

(15) *The effect of vitamin C.* Murlin, Marshall and Kochakian (1941), in carrying out protein metabolism experiments on adult male subjects, studied the effect, on the biological value of cereal proteins, of adding additional vitamins of the B group to a diet approximately adequate in these factors. A small increase was observed as the result of adding these supplements, but it was not satistically significant.

Experiments were conducted in Dacca on a human subject (A.K.M.) with the object of discovering whether a large intake of vitamin C influenced the biological value of pulse proteins. One hundred mg. of vitamin C were given as an addition to the experimental diets, with the results shown in Table 11.

TABLE 11.

Effect of vitamin C administration on the biological value and digestibility of pulse and soya bean proteins.

(Experimental subject—A.K.M.)

	Biological value		Digestibility co-efficient	
	without vit. C.	with vit. C.	without vit. C.	with vit. C.
Soya bean, Kashmir ..	42·0	42·0	88·0	88·5
Soya bean, Punjab I ..	59·0	61·0	92·0	95·0
Soya bean, Punjab II ..	56·8	59·0	91·0	91·0
Bengal gram	64·0	66·0	94·0	95·6
Red gram	60·0	63·0	90·0	92·0

The addition of vitamin C had no effect on biological values or digestibility co-efficients. It may also be added that vitamin C did not influence urinary and faecal excretion of nitrogen while the subject was taking the nitrogen-free diet.

CHAPTER V.

THE EFFECT OF SOYA BEAN IN SUPPLEMENTING RICE DIETS

(1) A series of experiments was carried out to determine the effect on the growth of young rats, fed on a diet largely composed of rice, of the addition of soya bean and other pulses as supplements. Before these are described, brief reference may be made to certain experiments recorded in the literature which were concerned with the value of soya bean as a supplementary food.

(2) Wan (1931) fed rats on a diet composed of "soya bean-milk powder", one part, and whole wheat, 2 parts, with the addition of sodium chloride. Normal growth was not obtained, whereas it occurred when whole milk was included in the diet in place of "soya bean-milk powder", and in the same proportion. When the soya bean wheat diet was supplemented with substances rich in vitamins A, B complex, and D, and a complete salt mixture, the growth of rats was improved, but was still inferior to that obtained with the diet containing dried milk powder. McCollum, Simmonds and Parsons (1921) had previously reported that young rats fed on synthetic diets at a 9 per cent level of protein intake showed sub-normal growth when all the protein was supplied by soya bean, but much better growth when soya bean furnished 6 per cent of the protein and milk 3 per cent. Harris, Clark and Lockhart (1944) in experiments on rats obtained the best growth with a bread containing 3 per cent milk solids and 3 per cent soya bean flour which was nearly double that on wheat bread alone with no supplements. Aykroyd and Krishnan (1937) in experiments in which young rats were fed on a "poor rice diet" resembling that consumed by poor rice-eaters in India, found that the addition of soya bean in quantities approximately equivalent to 3 ozs. in a human diet, had little effect in enhancing the growth rate. Half this quantity of dried milk, on the other hand, produced much more rapid growth when given as a supplement. Basu, Nath and Mukherjee (1937) from experiments on rats concluded that there was no supplementary relationship between the proteins of wheat and those of soya bean or field pea. In contrast with the above findings Jones and Divine (1944) reported from growth experiments on rats that a diet made up of a mixture of 15 parts of soya bean flour and 85 parts of wheat flour was superior to a diet wherein skimmed milk powder replaced the soya bean flour to the same extent. In general it appears from the literature that soya bean is inferior to milk as a supplement to cereal or other diets.

A. *Experiments with a "poor rice diet"*. (3) It has been shown that the biological value of soya bean proteins is of the same order as that of certain common Indian pulses. On the other hand, soya bean contains more protein than any of these pulses. It is generally agreed that rice diets, as consumed by the poorer classes in India, are deficient in proteins. Hence it was decided to carry out experiments in which a poor rice diet was supplemented by equal quantities of soya bean and other pulses, and the effect of the various supplements on the growth rate of young rats observed. It was felt that this would provide an indication of the general nutritive value of soya bean, including its value as a source of protein in comparison with that of pulses in common use, and throw light on the question whether soya bean should be encouraged as a supplementary food in India.

(4) The composition of the rice diet, and its content of various nutrients are shown below.

	Parts
Milled raw rice	20·0
Non-leafy vegetables (*e.g.* brinjal)	1·0
Green plantain	0·5
Cabbage	0·5
Groundnut oil	0·5

Composition.

	Per cent
Protein	6·25
Fat	2·61
Carbohydrate	71·20
Ash	1·28
Calcium	0·027
Phosphorus	0·102
Calcium—phosphorus ratio	1 : 3·8

(5) The rice diet in general resembled the kind of diet consumed by poor rice eaters, except that it did not contain any pulse. The various pulses were included in the diet as supplements. As regards its composition, the rice diet was poor in protein, fat, calcium and in various vitamins. The calcium/phosphorus ratio was also unsatisfactory.

(6) Twelve young rats, 40 to 50 g. in weight and including equal number of both sexes, were used as experimental groups. One group was fed the basal diet shown above, while other groups received diets in which 3 parts of soya bean or other pulses replaced an equivalent quantity of rice. The diets were cooked and given *ad lib*. The rats were fed on these diets for a period of 9 weeks and weighed at weekly intervals. The average rate of growth obtained with the various diets was taken as the criterion of their nutritive value.

Two series of experiments were carried out, in 1942 and 1943 respectively. Mean weekly increase in weight in case of both series is shown in Table 12, while increase in body weight per g. of diet consumed is shown in Table 13.

TABLE 12.

Effect on growth of young rats of different varieties of soya bean and other pulses in supplementing a rice diet (diets cooked).

	Average increase in body weight per rat per week (g.)				
	Work carried out at				
	Bombay.	Coonoor.	Dacca.	Lahore.	Average.
Basal Diet (B.D.) (rice diet) I	0·20	3·00	2·62	0·75	1·64
Basal Diet (B.D.) (rice diet) II	..	3·50	2·00	−0·27	2·75
B.D. + Soya bean, Manchurian	2·15	4·50	3·59	1·31	2·89
B.D. + ,, ,, Kashmir	..	5·60	3·20	0·82	3·21
B.D. + ,, ,, Punjab I	..	5·10	6·25	..	5·68
B.D. + ,, ,, Punjab II	..	5·80	4·00	..	4·90
B.D. + ,, ,, Lyallpur	..	5·20	..	..	5·20
B.D. + Bengal gram, Sample I	2·25	5·20	3·25	2·04	3·19
,, ,, ,, Sample II	..	6·10	3·50	1·10	3·57
B.D. + Red gram, Sample I	1·70	4·30	2·83	..	2·94
,, ,, ,, Sample II	..	6·20	3·40	..	4·80
B.D. + Green gram, Sample I	1·40	4·20	3·25	..	2·95
,, ,, ,, Sample II	..	4·90	..	..	4·90

Table 13.

Effect of food consumed on growth of young rats of different varieties of soya bean and pulses when supplementing a rice diet (diets cooked).

	Average increase in body weight per rat per week (g.)			Average consumption of food per rat per week (g.)			Food consumption per g. increase in body weight (g.)		
	EXPERIMENTS CONDUCTED AT								
	Bombay.	Coonoor.	Lahore.	Bombay.	Coonoor.	Lahore.	Bombay.	Coonoor.	Lahore.
Basal Diet (B.D.) (rice diet) I ...	0·20	3·0	...	25·2	74·0	...	126·0	24·6	...
do. do. do. II ...	...	3·5	−0·27	...	90·6	22·14	...	25·9	...
B. D. + Soya bean, Manchurian ...	2·15	4·5	...	37·1	80·0	...	17·2	17·7	...
do. do. Kashmir ...	...	5·6	0·82	...	115·4	23·20	...	20·6	28·4
do. do. Punjab I ...	...	5·1	...	...	115·9	...	...	22·7	...
do. do. Punjab II ...	...	5·8	...	...	114·4	...	...	19·8	...
do. do. Lyallpur ...	...	5·2	...	...	116·1	...	...	22·4	...
B. D. + Bengal gram, Sample I ...	2·25	5·2	...	37·1	88·0	...	16·5	16·9	...
do. do. Sample II ...	...	6·1	1·10	...	106·4	25·07	...	17·5	22·7
do. + Red gram, Sample I ...	1·70	4·3	...	35·7	85·0	...	21·0	19·7	...
do. do. Sample II ...	...	6·2	...	...	109·3	...	...	17·7	...
do. + Green gram, do. I ...	1·40	4·2	...	33·6	87·0	...	24·0	20·6	...
do. do. do. II ...	...	4·9	...	...	106·1	...	...	21·6	...

(7) The rates of growth observed on the various diets varied in the different laboratories, rates being generally highest in Coonoor. The relative growth-enhancing effect of the various supplements was, however, reasonably constant. On the basal diet poor growth was obtained and the addition of the various pulses led to some improvement, suggesting that pulses are useful and necessary supplements to poor rice diets. The addition of soya bean did not, however, produce better growth than the addition of the other pulses, in spite of the higher protein content of soya bean.

(8) As regards growth in relation to food intake (Table 13), it may be noted that the basal rice diet gave the poorest results. The results obtained with the various pulses were more or less of the same order, but there was some indication that the diet containing Bengal gram was converted more efficiently into tissue than the diets containing soya bean or other pulses given in the experiments.

B. *The addition of soya bean and other pulses to a rice diet fortified with calcium and vitamins.* (9) The poor rice diet was, as has been pointed out, highly deficient in various constituents. It was felt that the supplementary effect of soya bean might be more apparent if some of these deficiencies were made good. Accordingly experiments were carried out in which certain nutrients were included in the basal diet. Calcium lactate was added in the proportion of 0·70 g. of calcium to 700 g. of the basal diet. Seven hundred grammes approximates to human daily intake, and an addition of calcium of the above order would cover human daily requirements. The actual proportions, calculated in this manner, were 0·13 g. of calcium lactate per 22·5 g. of the basal diet. In one experiment, carried out in Lahore, calcium lactate alone was included in the basal diet. In other experiments vitamin A and the B vitamins were given in addition to calcium. Vitamin A was given in the form of shark liver oil, which was included in the basal diet in quantities sufficient to supply 300 International Units of vitamin A per rat per day. To supply the B vitamins a slightly acid aqueous extract of yeast was given, in amounts equivalent to 2 grammes of dried yeast daily per rat.

(10) The addition of calcium lactate improved growth on the basal diet. Average growth obtained on the basal diet containing calcium, and the same diet including soya bean and Bengal gram, is shown below :

	Average increase in body weight per rat per week (g).
Basal diet (rice diet + calcium lactate) ..	4·6
Basal diet + Soya bean, Kashmir variety ..	6·1
Basal diet + Bengal gram	7·6

The supplementary effect of soya bean and Bengal gram under these experimental conditions was of the same order, that of the latter being slightly superior.

(11) The analysis of the "fortified" rice diet containing calcium and vitamins, with and without pulse supplements, is given in Table 14. Table 15 shows mean weekly increase in body weight, and Table 16 food consumption in relation to increase in weight on the various diets.

TABLE 14.

Analysis of some of the experimental diets.

	Moisture %	Ash (mineral matter) %	Protein %	Fat (ether extractives) %	Carbohydrate %	Calcium (Ca) %	Phosphorus (P) %	Iron (Fe) mg. %
Basal Diet (B.D.) (rice diet 'fortified') ...	17·81	0·502	7·16	2·90	73·63	0·117	0·115	5·51
B. D. *plus* Soya bean, Kashmir ...	14·16	1·387	10·38	5·24	68·83	0·141	0·242	9·59
B. D. *plus* Soya bean, Punjab I ...	15·75	1·486	11·53	5·62	65·61	0·145	0·251	11·77
B. D. *plus* Soya bean, Lyallpur ...	14·79	1·595	10·43	5·48	67·71	0·139	0·232	10·10
B. D. *plus* Bengal gram ...	15·54	1·228	8·60	3·25	71·38	0·150	0·240	15·17

TABLE 15.

Effect on growth of rats of different varieties of soya bean and other pulses in supplementing a rice diet fortified with calcium lactate, yeast extract and shark liver oil (diets cooked).

	Average increase in body weight per rat per week (g.)			
	Work carried out at			
	Coonoor.	Dacca.	Lahore.	Average.
Basal Diet (B.D.) (rice diet 'fortified')	7·3	6·1 5·9	7·9	6·8
B.D. + Soya bean Kashmir ..	7·1	5·5	11·1	7·9
B.D. + ,, Punjab I ..	7·3	8·7	..	8·0
B.D. + ,, Punjab II ..	9·0	7·6	..	8·3
B.D. + Bengal gram ..	9·0	7·5	12·0	9·5
B.D. + Red gram	9·2	7·2	..	8·2
B.D. + Green gram	9·0	..	..	9·0

TABLE 16.

Effect of food consumed on growth of young rats of different varieties of soya bean and pulses when supplementing a rice diet fortified with calcium lactate, yeast extract and shark liver oil (diets cooked).

	Average increase in body weight per rat per week (g.)	Average consumption of food per rat per week (g.)	Food consumption for one gramme increase in body weight (g.)
Basal Diet (B.D.) (rice diet, 'fortified')	7·3	108·1	14·8
B.D. + Soya bean, Kashmir ..	7·1	109·6	15·4
B.D. + Soya bean, Punjab I ..	7·3	109·6	15·0
B.D. + Soya bean, Punjab II ..	9·0	110·6	12·3
B.D. + Bengal gram ..	9·0	108·3	12·0
B.D. + Red gram	9·2	109·2	11·9
B.D. + Green gram	9·0	110·6	12·3

(12) The addition of calcium and vitamins to the basal diet very considerably enhanced its growth-promoting properties for rats. Similar results in this respect were obtained in all the laboratories. The inclusion of pulses in the "fortified" diet did not have any very marked effect on growth. This shows that in typical rice diets in India lack of adequate amounts of calcium and vitamins is to a greater extent the limiting factor than the lack of protein. The difference as regards weight increase in favour of the diets containing pulses (including soya bean) was of the order of 15 per cent, whereas the addition of pulses to the same diet without the inclusion of the calcium and vitamins more than doubled the growth rate. It is to be remarked that in these experiments, as in previous ones, the inclusion of soya bean in the diet produced no better effect on growth than the inclusion of Bengal gram, green gram or red gram.

(13) The results shown in Table 16 were obtained in Coonoor. Intake of food per g. increase in weight was considerably lower with the "fortified" diet than the rice diet alone. Under these experimental conditions growth on the diets containing soya bean was less per unit weight of food consumed than on the diet containing the other pulses. The difference was not, however, very large.

C. *The effect of autoclaving on supplementary value.* (14) Similar experiments to those described above were carried out, with the difference that autoclaved instead of cooked pulses were included in the fortified rice diet. The pulses after being powdered were autoclaved in steam at 120°C. for two hours, and subsequently air-dried. The results of these experiments, which were done in Dacca, are shown in Table 17. For purposes of comparison corresponding data for cooked pulses from the previous series of experiments are included.

TABLE 17.

Effect of autoclaving on growth of rats of different varieties of soya bean and other pulses in supplementing a rice diet fortified with calcium lactate, yeast extract and shark liver oil (diets cooked).

	Treatment	Average increase in body weight per rat per week (g).
Basal Diet (B.D.) (rice diet, fortified)	C	6·0
B.D. + Soya bean, Kashmir ..	C	5·5
" " " ..	A	6·8
B.D. + Soya bean, Punjab I ..	C	8·7
" " " ..	A	9·1
B.D. + Soya bean, Punjab II ..	C	7·6
" " " ..	A	8·0
B.D. + Bengal gram ..	C	7·5
" "	A	6·6
B.D. + Red gram	C	7·2
" "	A	6·4

Note:—C = Diet cooked over a fire.
A = The soya been or pulse powder supplement autoclaved in steam at 120°C for two hours and then dried. This was incorporated in the cooked rice diet.

(15) Growth on the diets containing autoclaved soya bean was slightly superior to that obtained when the same diets were given after simple cooking. On the other hand, the autoclaving of the other pulses produced the opposite effect. This agrees with observations referred to earlier in this report.

CHAPTER VI.

DISCUSSION.

(1) Within the range of the experiments sponsored by the Sub-Committee, soya bean was not found to be superior in nutritive value to pulses now in common use in India. It cannot be of course claimed that the enquiry covered all aspects of the subject and further work can with advantage be carried out. The experiments in which soya bean and other pulses were fed as supplements to a poor rice diet are perhaps the most informative of those described in this report. Though soya bean is superior to other pulses in its "net" protein value, fat, mineral and vitamin contents, yet it has not proved itself a better supplement to a simplified rice diet than other pulses. This apparent anomaly is difficult of explanation. It should, however, be pointed out that in the series of experiments herein reported, the diets were fed *ad lib* thus providing sufficient calories for the full needs of the experimental animals. It is possible that soya bean may prove superior to other common Indian pulses if it were used as a supplement to simplified cereal diets which resemble those commonly consumed in this country and which are quantitatively inadequate, since Gounelle, Bachet and Marche (1942) successfully treated patients suffering from hunger oedema with a supplement of soya bean. This assumes added importance in India where millions of people do not even have two meals a day and are therefore getting a diet inadequate in calories. But so far as the present experiments go it is difficult to draw from these any conclusion other than that no advantage would accrue from replacing common pulses by soya bean in ordinary Indian diets.

(2) Brief reference may be made here to the question of palatability. Unprocessed soya bean contains unpalatable aromatic substances which would impair its popularity as a pulse, if used in the same way as other pulses in this country. Various methods of removing the unpleasant aromatic substances have been devised—*e.g.* the Berczeller and the Horvath processes—but these can be carried out only in factories. While processed soya bean flour would no doubt be more acceptable than the untreated bean, it could not readily replace familiar pulses in the diet of the bulk of the population. In general, even processed soya bean flour has never become a popular article of diet. Such flour has been consumed by the civil population in England during the war, and also by the British army. It has been accepted as a war necessity, but certainly not relished. The attitude of the army towards the sausages known as "soya links" abundantly confirms this statement.

(3) In countries where soya bean is an important food *e.g.*, in China, numerous special preparations are made from the bean and it appears that soya bean is usually consumed in the form of such preparations and not as a pulse which is cooked and added to rice and other dishes as is the habit in this country with regard to pulses. The popularisation of the use of soya bean in India in the same way as in China would entail the education of the people in such methods of preparation, which might prove a difficult matter. Before an educational campaign to popularise unfamiliar soya bean preparations was undertaken, it would be necessary to be sure that results useful, from the standpoint of nutrition, would be obtained. The experiments described in this report, as far as they go, do not suggest that the substitution of common Indian pulses by soya bean would be of any striking advantage.

(4) Soya bean is, of course, a crop of considerable industrial importance. It is a rich source of oil which is used in the manufacture of margarine and has many industrial uses ; for example, it provides plastics which are basic to many branches of modern industry. In the United States soya bean is extensively cultivated as an industrial crop. With the growth of industry in India its cultivation for industrial purposes may be called for. Soya bean flour suitably processed in factories, produced, as in the United States, as a by-product of the development of soya bean cultivation for industrial uses, may, as already remarked, be more acceptable as human food than the untreated pulse. Soya bean milk, suitably "fortified" by the addition of minerals and vitamins, might be of value in the feeding of young children. Again soya bean is a leguminous crop of value as fodder and in the rotation of crops, and the part it could play for these purposes in Indian agriculture is worthy of investigation.

CHAPTER VII.

SUMMARY AND CONCLUSION.

(1) Soya bean has been cultivated in the Far East from early times and is an important article of diet in China and Japan. In the United States of America it has, during recent years, been extensively grown, mainly as an industrial crop. It has been introduced into India, but is cultivated only on a limited scale.

(2) The richness of soya bean in protein and fat has focused attention on its possible value as a supplement to the diet of the poorer classes in India and much discussion of this question has taken place. Preliminary experiments suggested that soya bean was not superior to common Indian pulses as a supplement to ill-balanced rice diets, but in view of the differences of opinion of the matter, and the enthusiastic advocacy of soya bean on the part of a number of scientific workers and laymen, the Nutrition Advisory Committee, I.R.F.A., at a meeting held in December, 1941, constituted a sub-committee on soya bean to study the problem in detail. A conjoint investigation was initiated by the Sub-Committee in four different laboratories : the Biochemical Laboratory, University of Dacca ; the Physiological Laboratory, the Seth G. S. Medical College, Bombay ; the University Chemical Laboratories, Lahore ; and the Nutrition Research Laboratories, Coonoor.

(3) Soya bean has a crude protein content ranging from 30 to 50 per cent, which is nearly double that of common Indian pulses. The average biological values reported in the literature for soya bean proteins (cooked) are 64 (balance sheet method) and 1·57 (growth method). Most of the amino acids essential for nutrition are present in fair quantities but there is a deficiency of cystine and methionine, as shown by rat-growth experiments. The addition of these amino acids improves the biological value of soya bean proteins. The improvement in biological value caused by autoclaving is thought to be due to the liberation of a previously unavailable cystine fraction.

(4) The fat content of soya bean is of the order of 20 per cent whereas other pulses in general contain little fat. It is a fairly good source of vitamin B_1, calcium, phosphorus and iron, but not rich in carotene, riboflavin and nicotinic acid. Very little starch is present.

(5) Soya bean milk and other soya preparations have been used in various parts of the world in the feeding of infants and young children. The supplementing of such preparations by vitamins and minerals is necessary. Soya bean milk even when supplemented is not, however, equivalent to cow's milk in nutritive value and preliminary trials and experiments would be required before advocating its use in India. The successful feeding of infants with a mixture of soya bean flour and dried whole milk has been reported.

Experimental Results.

(6) A growth experiment on rats with soya bean milk extending over a period of eight weeks was carried out in Dacca. One group received a simplified rice diet alone while two other groups received in addition 10 ml. each of cow's milk or soya bean milk per rat per day. The average weekly increase in body weight of the rats receiving a supplement of soya bean milk was slightly lower than that on cow's milk but more than double that on the rice diet alone with no supplement.

A school feeding experiment was carried out in Lahore in which 1 oz. of cooked soya bean, 1 oz. of black gram and 12 ozs. of whole liquid milk were given respectively to groups of boys aged 13 to 15 for 9 months. The boys belonged to the poorer classes and were living on a wheat diet deficient in protective and supplementary foods. The group receiving soya bean showed no advantage, in respect of increase in weight, over that receiving black gram.

(7) The biological values and the digestibility coefficients of the proteins of soya bean, Bengal gram, green gram and red gram were compared by the balance sheet method using adult rats, protein being fed at a 10 per cent level of intake. The experimental diets were steam-cooked. The biological value and digestibility coefficient of soya bean were found to be of the same order as those of the other pulses. Since, however, the crude protein content of soya bean is nearly twice that of the other pulses, the "available" or "net" protein content of the former was found to be $1\frac{1}{2}$ times to twice that of the latter.

Autoclaving in steam for 2 hours at 125°C. increased the biological value of soya bean proteins, but led to a slight decrease in the case of the other pulses. It had no marked effect on the digestibility coefficients.

(8) Similar results as regards relative biological values were obtained by the growth method, in which young rats were used and protein was supplied at a 10 per cent level of intake.

(9) Biological values and digestibility coefficients were determined by metabolism experiments on human beings. Here again the biological value of soya bean proteins was found to be of the same order as that of the proteins of the other pulses. The administration of 100 mg. of ascorbic acid daily to an experimental subject did not influence the results of similar experiments.

(10) The value of soya bean, Bengal gram, etc., as supplements to a poor rice diet was investigated, using the growth of young rats as a criterion. The rice diet was given alone, and supplemented by 13 per cent of the pulses under test, for a period of 9 weeks. The addition of soya bean and the other pulses enhanced the growth-promoting effects of the basal rice diet, but the supplementary effect of soya bean was not found to be superior to that of the other pulses. Growth per unit weight of the

test diets consumed was also investigated. The basal rice diet gave the poorest results. The diets containing soya bean were not superior to the other test diets in this respect ; there was some indication that the diet including Bengal gram was more efficiently converted into tissue than the other diets.

(11) In a further series of experiments the basal rice diet was "fortified" with calcium lactate, shark liver oil to supply vitamin A, and yeast extract to supply the B group of vitamins. This improved its growth-promoting properties. Soya bean and other pulses were included in the "fortified" diet at a 13 per cent level. Soya bean showed no superiority as regard growth-promotion under these experimental conditions and the supplementary effect of all the pulses was less marked than in the previous experiments in which no addition of vitamins and minerals to the basal diet was made. The autoclaving of soya bean and the other pulses did not produce any substantial change in results.

(12) Although soya bean contains more of fat, minerals, vitamins and 'available' proteins than other pulses, it has, for some unknown reason, not proved itself superior to other pulses within the range of experiments reported here. It is, however, possible that soya bean may, as has been pointed out elsewhere, prove a better supplement than other pulses to typical Indian diets which are quantitatively inadequate and based on cereals. Further work on this aspect is desirable.

(13) Taking the results obtained so far into consideration, the Sub-Committee is of the opinion that as a supplement to typical Indian diets based on cereals, but supplied adequate in quantity, soya bean has no special advantage over common Indian pulses.

The Sub-Committee is not in a position therefore to advocate *immediately* the encouragement of the production of soya bean on a wide scale in India for use as a substitute for Indian pulses. The question should, however, be reconsidered if and when further evidence on the nutritive value of soya bean becomes available.

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